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# MDA Update

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## Building With Atoms —*by Patrick Hartary*

*Small-scale specialists are creating a technology revolution in the way materials, devices, and systems are manufactured and perform.*

What if scientists could manipulate atoms or molecules, one by one, and place them in precise patterns of their choosing?

Well, consider a medical device that travels through the human body to seek out and destroy small clusters of cancerous cells before they can spread. Or a box no larger than a sugar cube that stores all of the information housed in the Library of Congress. Or materials much lighter than steel that possess 10 times as much strength.

They don't exist yet. But scientists believe they can create them in the not too distant future through basic research in nanotechnology, the manipulation of materials at the atomic and molecular level.

Within the past few years, a growing number of companies, including four funded by BMDO, now the Missile Defense Agency, have brought this emerging field out of the lab and into the marketplace. They are focusing on basic nanoscale materials—whose characteristic dimension is less than 100 nanometers or a fraction of the width of a human hair—that can be used in existing military and commercial products or to build entirely new ones.

Take a journey with us into this big little world where we'll explore these companies who are working to make nanotechnology a reality, the tools they're using to create nanoscale materials, and the nanotech products they're commercializing.

### Nanomat

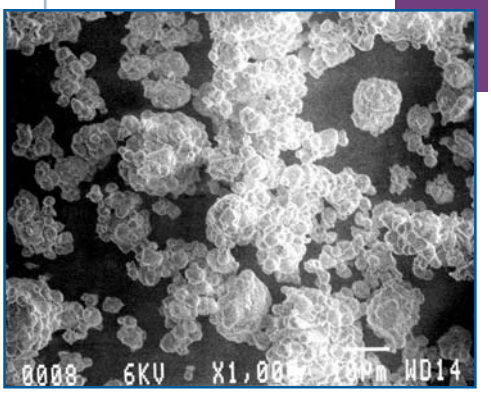
Nanomat, Inc. (North Huntingdon, PA), is using a wide variety of techniques to produce nanomaterials with potential for large-scale production. These techniques include sol-gel synthesis, mechanochemical and chemical synthesis, aerosol processing, high-energy ball milling, and hydrothermal processing.

The company is already producing significant quantities of nanocrystalline calcium carbonate ($CaCO_3$) and talc. In a process called alkaline bleaching, which is environmentally less hazardous than acid bleaching, $CaCO_3$ and talc can be used to brighten paint, paper, and plastics. Talc can also be used to reinforce polymers.

Large batches of titanium dioxide ($TiO_2$) and iron are also being manufactured. $TiO_2$ can be used in sunscreen lotion to block harmful ultraviolet rays and in pills and lotions to make them easier to swallow or apply. Iron is being made for ferrofluids and magnetorheological fluids for biomedicine (e.g., targeted drug delivery, DNA tagging, and MRI contrast agents) and automotive applications (e.g., active suspensions).

With BMDO SBIR funding, Nanomat is gearing up to produce large quantities of aluminum oxynitride (AlON), an ideal replacement for sapphire in radar and infrared domes or windows protecting sensor packages on missiles or aircraft. AlON has a cubic symmetry, resulting in isotropic properties. It also displays greater than 80-percent in-line transmission in

Continued on page 14




***Microscopic view.*** *Aluminum oxynitride, with particle sizes between 1 and 2 microns, is shown above courtesy of scanning electronic microscopy. With BMDO SBIR funding, Nanomat is developing a more cost-effective way to make this nanoscale material.*

MDA Update

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## FROM THE EDITOR

### WHAT'S IN A NAME? CHANGE

If you haven't heard already, the Ballistic Missile Defense Organization (BMDO) is no more. Actually, the organization itself isn't gone, only the name is.

In January, the Department of Defense redesignated BMDO as the Missile Defense Agency (MDA). The newly established agency will focus on four top priorities:

- To defend the United States, deployed forces, allies, and friends from ballistic missile attack.
- To employ a Ballistic Missile Defense System (BMDS) that layers defenses to intercept missiles in all phases of their flight (i.e., boost, midcourse, and terminal) against all threats.
- To enable the Services to field elements of the overall BMDS as soon as practical.
- To develop and test technologies; use prototype and test assets to provide early capability, if necessary; and improve the effectiveness of deployed capability by inserting new technologies as they become available or when the threat warrants an accelerated capability.

Elevating BMDO to agency status underscores the national priority and mission emphasis on missile defense. The current director, Air Force Lt. Gen. Ronald T. Kadish, has been given a new title: Director, Missile Defense Agency. Kadish's task is to establish a single program to develop an integrated missile defense system.

For more information, visit MDALINK at http://www.acq.osd.mil/bmdo/bmdolink/html/bmdolink.html.

Consistent with the establishment of MDA, the *BMDO Update* newsletter will now be called the *MDA Update*. Its purpose, however, remains the same: to link American businesses with innovative missile defense technology.

### New Helmsman

Speaking of change, there's a new SBIR program manager at MDA. His name is Frank Rucky (pronounced rookie). Mr. Rucky comes to MDA from the U.S. Navy where he managed SBIR technology development. On page 3, you'll find more information about Mr. Rucky's current and future visions for MDA's SBIR program.

### Helpful Links

This newsletter typically includes a page that discusses an important business issue facing high-tech start-ups today. For example, issues such as how to develop a business plan, plan strategically, structure stock ownership, and hire business students have been discussed. This information has generated little feedback from our readers so we are trying something new. On page 5, you'll find several hyperlinks to valuable online resources for business development. We will keep updating these links as we find them. In the meantime, please send us some feedback as to whether or not these links are helpful.

**Patrick Hartary**
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## MDA ANNOUNCES NEW SBIR PROGRAM MANAGER

MDA has announced a new manager, Mr. Frank Rucky, for its SBIR program and has refined the program to maximize technology investment for direct insertion into missile defense systems. Mr. Rucky comes to MDA from the Navy, and for the past five years he has run the SBIR program for Program Executive Officer (PEO) Theater Surface Combatant—the largest PEO for NAVSEA—and has resided on NAVSEA's Board of Directors for SBIR. Mr. Rucky has also worked on various technology programs, dealing mostly with missiles and missile-related products. In a recent interview, Mr. Rucky told the *MDA Update* more about changes coming to the new agency's SBIR program.

***MDA Update:*** *Will commercialization continue to be emphasized in the MDA SBIR program?*

**Rucky:** Yes. Commercialization is the major thrust of SBIR. We are going to use commercialization with a capital "C," meaning that we will encourage participation from both public and private backers. We realize that many SBIR products will first actually go out to the private sector and, as such, we will support those products in areas that are clearly of interest to MDA. We're also trying to open up opportunities for small businesses to access more information about MDA needs and avenues for them to insert their products into MDA programs. We have done this by formalizing a system for points of contact and liaisons into the segments and elements.

***MDA Update:*** *Will sensors and electronics continue to represent the lion's share of funding for MDA SBIR?*

**Rucky:** This organization, by its nature, is mostly interested in sensors and electronics because those areas are the primary drivers. I suspect the programs will continue to largely emphasize sensors and electronics. There will likely be some other emphasized areas not previously stressed. I think we are going to see better-articulated requirements within the SBIR topics. I think that's a very positive thing. In addition, MDA is putting together a National Industrial Team (NIT). My feeling is that SBIR will leverage this team very heavily. The NIT could serve as an avenue for partnerships with large corporations, allowing the small businesses to productize their R&D and start developing long-term relationships with contractors to the MDA segments and elements.

***MDA Update:*** *When is the next solicitation?*

**Rucky:** We will for the first time participate in the ".2" solicitation, for which proposals are due in August. I'm anticipating that MDA will have somewhere between 30 and 40 topics in that solicitation, most of which will be more specific in nature. The topics will include points of contact with whom to discuss the contents during the presolicitation phase, which begins in May.

***MDA Update:*** *How will previous Phase I winners submitting Phase IIs be treated with the current changes in the solicitation?*

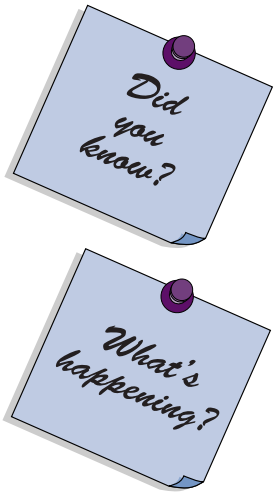
**Rucky:** Previous Phase I winners are going to be treated exactly as written in their proposal solicitation. They can submit their Phase II proposal at anytime. That is what BMDO as an organization had committed to and that is what the MDA SBIR program is committed to. They had participated in this program in good faith. And we intend to treat them in good faith. Now, starting with this current solicitation, Phase II proposals will be by invitation only. The decisions as to who will be invited in this current solicitation will be in the October time frame.

***MDA Update:*** *Do you have other thoughts that you would like to share with the* MDA Update *audience?*

**Rucky:** MDA SBIR partners MDA with small business. We will do our best to help them be successful because we know that their success will help create MDA products in the future. It's going to be a partnership. We're hoping to get them more access into MDA Program Segments and Elements to give the small businesses better product ideas that will address MDA needs. We're not going to lose sight of the fact that this is a dual-use program. We're going to look for opportunities to take advantage of dual-use opportunities because there are many potential products that in the near term won't transition to MDA but in the far term will have an impact.

*—L. Aitcheson*

***New helmsman.*** *Frank Rucky, who previously worked on various U.S. Navy technology programs, is now steering the MDA SBIR program.*




For more information about MDA's SBIR program, visit www.winbmdo.com.

ADVANCED MATERIALS

## WORRIED ABOUT BIOTERRORISM? THINK SURFACE AREA

***Breathing easier.*** *Pictured above is a prototype of IntraMicron's escape mask. With the help of a carbon-metal composite originally developed for BMDO, IntraMicron can make this mask compact and light enough for rescue personnel to quickly distribute thousands to people at the scene of a disaster.*

A new class of composite materials designed to store more electrical charge has found a new niche removing chemical and biological agents from the air we breathe. The composites were developed at Auburn University in the early 1990s to make smaller, lighter capacitors for BMDO antimissile systems. Last year, the technology was licensed exclusively to IntraMicron, Inc. (Birmingham, AL), which is currently focused on developing "air security" products with the composites.

High-surface-area carbon fibers within the composite provide the common link between the air security application and the capacitors, as this surface area allows the material to store more charge in a given volume or more effectively trap harmful air particulates. Surface area alone is not enough to do these jobs, though, so Auburn researchers developed techniques for combining the carbon fibers with various metals to get the right chemical and electrical properties within the composite. With this control over composite properties, the technology has a laundry list of commercial uses from biotechnology to fuel cells. IntraMicron chose air security as the best place to focus its resources, a decision that was made last summer but turned out to be sadly prescient, as all three of IntraMicron's products could be useful in America's war on terrorism.

The first of IntraMicron's planned products are foldable, pocket-sized gas masks, which would allow emergency personnel to carry hundreds of the masks to the scene of an attack and efficiently distribute them or make gas masks more convenient to carry all the time if needed. In this application, the surface area of the carbon-metal composite allows it to trap contaminants more quickly than today's carbon-packed-bed filters, making the masks much less bulky. This quality also extends the useful life of the gas masks and makes them easier to breathe through since they operate over a much smaller pressure drop.

Also in the works are filters and sorbent canisters that continuously remove pathogens and other harmful materials from circulated air. IntraMicron's products would replace large carbon-packed-bed filters now in use only in buildings where clean air is critical, since they are large, expensive, and hard to service. In fact, the Auburn composite has already been designed into three different collective protection systems for government use. In addition, the company is looking at air circulation systems for airplanes, which could protect pilots and passengers from hijackers using chemical and biological weapons to gain control of a plane, or protect passengers from more everyday germs circulating in the cabin.

Finally, IntraMicron is developing animal tags that trap pathogens for later analysis. While these tags wouldn't prevent infection, they would allow health officials to pinpoint the location of an outbreak when checked periodically during the animal's trip from the farm to the food processor. These checkpoints would allow health officials to determine the source of the disease—whether natural or introduced by terrorists—and rapidly locate and quarantine only affected areas. By doing so, they could prevent the wholesale slaughter of livestock as occurred during Europe's recent mad-cow and hoof-and-mouth scares.

IntraMicron has recently closed a private placement round of financing that will allow the company to scale up manufacturing of the material and the end products.

*—T. Lynch*

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**"There ain't no rules around here. We're trying to accomplish something!"**

**—Thomas Edison**

## NO STRAIN, NO GAIN

Smart parts that report their condition under stress are usually expensive. A new strain sensor made out of nickel, iron, and copper might change that equation.

With the help of BMDO funding, Sensortex, Inc. (Kennett Square, PA), has developed a relatively inexpensive and lightweight strain sensor wire that, when stressed, produces a noticeable change in electrical output. The company's patent-pending Magstrain™ system can be embedded into any structure or composite to provide real-time, continuous monitoring data.

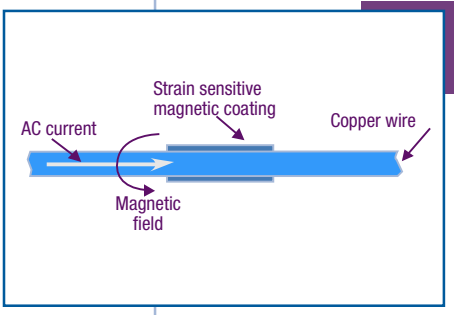
Magstrain is the outgrowth of BMDO-funded SBIR research at Sensortex to develop a lightweight, low-cost, multilayer coating for use as electromagnetic pulse shielding. While testing this technology, researchers discovered something odd: when flexed, the coating's magnetic properties changed. Although this was not desirable for shielding, it was very desirable for a sensor. So in 2001, BMDO funded the company for research on a strain sensor that could be embedded in a material and inexpensive enough for mass-market applications, thereby avoiding the problems associated with conventional foil strain gauges and the expense of fiber-optic sensors.

The secret to Sensortex's Magstrain is the small size of the sensor and knowing how to read the results. By coating a small diameter (75- to 125-micron) copper wire with a thin (10-micron-thick) nickel/iron film, and then driving an alternating current at low levels (50 to 500 milliamperes) through the wire, it creates a magnetic field with a voltage output at a base frequency. Even the smallest of changes in stress—such as when the wire is bent or twisted—produces changes in the frequency of the output, which can be monitored.

In partnership with Tokusen U.S.A., a manufacturer of wire for industrial applications, Sensortex intends to sell both the sensor wire and the electronic monitoring package needed to read the results. The company hopes to have a working system by the second quarter of 2002 and make it available for commercial sale by the third quarter of 2002.

Automobile parts and system manufacturers might be the first to take advantage of the new strain sensor because they are already heavily invested in using sensors, composites, and other low-cost, lightweight technologies to improve safety and reliability. However, airframe and aerospace engine manufacturers might also turn a designing eye towards lightweight sensors that promise instantaneous readout on stress and strain. Eventually, inexpensive thin-film nickel/iron-coated stress-sensitive sensors may find their way into bridges, dams, containment facilities, or other large-scale structures.

*—A. Gruen*




***Sensitive to stress.*** *Sensortex's Magstrain™ sensor is small, lightweight, embeddable, and inexpensive. A 10-micron-thick coating of nickel/iron film wraps around 75- to 125-micron-thick copper wire and produces a readable magnetic field that changes when the wire is bent or twisted.*

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## BUSINESS DEVELOPMENT RESOURCES FOR HIGH-TECH START-UPS

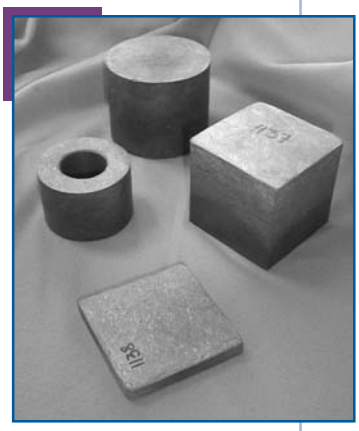
High-tech start-ups can find valuable business development information by following the two hyperlinks below.

- www.mitef.org/entrepreneurresources.htm
  This site, run by the MIT Enterprise Forum, Inc., provides links to other Web sites and presentation slides from Forum events. The links are organized by topics such as "Business Plans" and "Valuing Your Start-Up."

- web.mit.edu/entforum/www/hadzima/index.html
  Here, you can find column reprints from "Starting Up" by John Hadzima, which appear regularly in the *Boston Business Journal*. The columns are organized by topic, such as "Board of Directors" or "Employment/Employees."

Hyperlinks to additional business development resources can be found at http://www.mdatechnology.net/links.asp.

## CERACOM SPINOUT LEADS MATERIAL CLOSER TO MISSILE DEFENSE SYSTEMS



***Cost competitive.*** *Ceracom's Ceramight™ competes favorably with other high-end space materials in terms of cost. The process used to fabricate the composite material has been shown to cost 10- to 250-percent less than other methods for refractory components. This cost depends on the types of raw materials used in the process.*

*Both the ENVI™ process and Ceramight™ were developed by Triton Systems using BMDO SBIR funding.*

Commercialization does not preclude the use of a product or technology in defense applications. In fact, it usually is a key factor for insertion. A case in point is Triton Systems, Inc. (Chelmsford, MA), which last summer formed numerous partnerships and spun out a new 14-employee affiliate called Ceracom, Inc., to scale up and commercialize BMDO SBIR-funded advanced ceramic composites. Both BMDO systems and commercial interests had an eye for the same issues that Triton could address: low cost, high performance, and scalability.

Initially housed within Triton's walls, Ceracom plans to expand its operations into a 40,000 $ft^2$ facility within the next few months. The move will provide the company with enough space to scale up and mass-produce ceramic matrix composites (CMCs) using an Enhanced Vapor Infiltration (ENVI™) process.

ENVI is a low-cost process for making ultra light, ultra strong, ultra durable CMCs for high-volume markets. This process is similar to vapor infiltration and uses gas flow geometry, thermal gradients, and reactant pulsations to fabricate large and complex-shaped parts for a wide variety of applications ranging from thrust chambers for kinetic energy vehicles to golf clubs. "The key to ENVI's low cost is that components can be produced in one cycle with greatly reduced impregnation times," explained John Garnier, vice president of business development at Ceracom, "so its manufacturing cycle time is much faster—by an order of magnitude—than competing methods such as chemical vapor and polymer infiltration, which require multiple processing cycles."

The ENVI process creates ceramic components with excellent physical properties over a broad temperature range (cryogenic to 5,000°F). The materials can resist severe chemical environments while maintaining durability and toughness. In addition, using ENVI, fabricators can vary the thickness of CMC components and rapidly densify not only large, complex shapes, but also complex fiber architectures such as 3-D braids, weaves, or angle interlocked and tufted preforms.

Triton received a Phase II BMDO SBIR contract earlier this year to develop, in conjunction with SAIC and Aerospace Corporation, advanced lightweight affordable adaptive mirrors for space and airborne high energy lasers. Triton will also develop carbon/silicon carbide bi-propellant thrust chambers for kinetic vehicle divert and attitude control systems (DACs), focusing on advanced designs supplied by Rocketdyne and Atlantic Research Corporation for gel-propellants.

Another BMDO SBIR-funded technology that transferred to Ceracom is a high-end material and material process called Ceramight™. The refractory metal composite has high heat tolerance that exhibits virtually no erosion in rocket propulsion systems. The Ceramight process can be used to fabricate materials in many combinations at low cost and in batch quantities. Using it, fabricators form near-net-shaped green bodies through robust tape casting and consolidation. Green bodies are machined to vital tolerances and then sintered in a pressureless environment to form the finished components.

Ceramight material competes favorably with other high-end space materials in terms of cost, strength, and heat and corrosion resistance. So far, in tests, it was 10-times stronger than columbium at 2,350°F, and 20-times stronger than tungsten at 4,000°F. Its fracture toughness was 10-times that of silicon carbide's, and it did not oxidize or erode during liquid and solid rocket motor nozzle/chamber tests. Also, it retained its full strength at operating temperatures above 5,000°F.

Triton is working with major defense contractors to demonstrate Ceramight's feasibility in MDA applications such as integrated throat entrances for rocket nozzles (through Thiokol's and Pratt and Whitney's Chemical Systems Division), liquid divert attitude and control systems for the Theater High Altitude Area Defense missile (through Rocketdyne), and solid DACS (through Thiokol).

*—L. Aitcheson*

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## E-BEAM LITHOGRAPHY TOOL LEADS TO TECHNOLOGICAL ADVANCEMENTS ACROSS THE BOARD

It's not the Jetsons, but the 21st century is seeing the advent of long-range wireless communications with an increasing data rate, research devices growing in accuracy, and expanding technological advances in military machinery.

For technology to continuously evolve, companies need access to the latest techniques and equipment. Through NASA's Jet Propulsion Laboratory (JPL; Pasadena, CA), it is possible for the government and small companies to gain access to one of the few electron-beam lithography machines available for public research, and the experts needed to run it. BMDO's Innovative Science & Technology program funded JPL's first e-beam tool in 1986. In 1998, when the technology became outdated, BMDO, NASA, and JPL combined resources to acquire and house a new tool in the Microdevices Laboratory at JPL.

Researchers use e-beam lithography to write masks for optical lithography with stringent linewidth control and pattern placement specifications. This technology can write masks to less than 0.1 m on a variety of materials in almost any pattern, allowing researchers to work on the submolecular scale, compared to optical lithography tools that can only print 0.25 m features in development laboratories.

In particular, JPL's e-beam tool has been used to write masks and gratings for a prototype gallium nitride (GaN) power amplifier, which could advance wireless communications by lowering the cost and reducing the size of radar and satellite systems. Funded by BMDO, the Space and Missile Defense Command, and the Office of Naval Research, the program is intended to develop power amplifiers that can produce 20 watts of power at x-band and higher frequencies for higher-power radar detection. Current amplifiers offer only one to two watts of power.

JPL's e-beam tool has also written the fine gratings needed for tunable diode lasers (TDLs). BMDO and NASA funded JPL's development of TDLs for optical communications and gas-sensing applications. The TDL technology spun-off into two companies, ViaSpace Technologies and SpectraSensors, Inc. Know-how was transferred under JPL's Technology Affiliates Program. Each company holds licensing agreements with the California Institute of Technology to manufacture and market gas-sensing systems using TDL technology. The e-beam tool was used to make a TDL spectrometer for the Mars Explorer Polar Lander's thermal and evolved gas analyzer, which was intended to measure the amount of carbon dioxide and water vapor in samples of Martian soil. JPL's e-beam lithography tool has been involved throughout the life of TDL technology.

In addition, the e-beam tool wrote masks for JPL's quantum-well infrared photodetectors (QWIPs) program. JPL developed the QWIP focal plane arrays, which cover longer wavelengths and are more efficient at capturing infrared radiation than traditional arrays. ViaSpace acquired a license to commercialize JPL's BMDO-funded QWIP technology and spun-off QWIP Technologies, which fabricates products such as the QWIP Chip™ focal plane array. Technology transfer occurred under JPL's Technology Affiliates Program.

Though it is not for commercial purposes, JPL's e-beam lithography tool assists in the commercialization of many technologies and the advancement of their innovators. Researchers interested in using the e-beam lithography tool should contact Paul Maker.

*—T. Spitzer*

***Versatile tool.*** *An electron-beam lithography machine at the Jet Propulsion Laboratory has been used by dozens of researchers to push the limits for integrated circuit design.*

*DOD used JPL's e-beam tool to make convex gratings for the Air Force's Warfighter-1 program. The gratings were part of a satellite-based hyperspectral imager demonstration that detected and identified ground targets and conditions not seen by other satellites.*

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ELECTRONICS

## CHANGING THE FACE OF A SUBSTRATE

Dick Tracy's New Age wrist watch/cell phone was admired by every ten-year-old budding crime fighter. Now, this phone could become a reality using thin-film passive components developed by Integral Wave Technologies, Inc. (Fayetteville, AR).

Inductors, capacitors, and resistors are passive components that serve as the basic building blocks of virtually every circuit in every electronic product or system built today. Because of their prevalence, these components typically consume at least 85 percent of the real estate on the product's circuit board or system substrate. Using Integral Wave's thin-film technology will enable the product manufacturer to reduce the size of the circuit board or substrate by 85 to 90 percent, while simultaneously improving the electrical characteristics of each circuit.

*Using Integral Wave's thin-film technology will enable manufacturers to reduce the size of circuit boards and substrates by up to 90 percent while simultaneously improving the electrical characteristics of each circuit.*

Under a BMDO SBIR program to form on-die capacitors, Integral Wave is now extending its planar passive technology to wafer-level processes based on the company's ability to deliver capacitors offering high-capacitance densities yet which are at least 500-times thinner than the smallest discrete capacitors available today.

The company is working on two business strategies: package-driven and component-driven product/market applications. The package-driven strategy is centered on the company's ability to enable manufacturers of electronic products to design and produce more compact products and is targeted for the cell phone handset industry. The component-driven strategy is aimed at the microprocessor industry, which needs high performance components, especially in the area of microprocessor power supplies. Integral Wave is currently involved with companies from both industries.

In markets for high-performance microprocessor power supply decoupling, the first stage of Integral Wave's productization strategy is to integrate their passive thin-film capacitors directly into the existing chip packages. A later stage will pursue a more effective method, which is to embed the passive components directly into the chip package substrate. In handset applications, Integral Wave's final and most effective utilization of thin-film components is to embed both passive and active components in the package substrate—a process they are currently applying as they develop prototypes for several partnering companies. While the company is concentrating its effort on the cell phone and microprocessor industries, other potential avenues, such as automotive, military/aerospace, and medical devices and equipment are possible.

*—T. Spitzer*

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## UPCOMING REPORT TO HIGHLIGHT COUNTER-TERRORISM TECHNOLOGIES

Having witnessed the events surrounding September 11 in Washington and New York, we all recognize the need for a more secure homeland. Cutting-edge technology may help prevent further tragedies and fight the war on terrorism.

The MDA Technology Applications program is developing a new report featuring MDA-funded technologies with counter-terrorism applications. The report will outline preventive and aggressive counter-terrorism technologies including intelligent software, financial tracking systems, surveillance devices, sensors, and cyber security.

Examples include:

- Intramicron's microfibrous materials for chemical and biological sorbents filters,
- Frontier Technology's digital signal noise processing system for speech recognition enhancement,
- HNC's software for tracking financial transactions,
- Knowledge Based Systems' integrated data experimentation and fusion system for data mining and fusion, and
- Genex Technology's 3-D infrared camera for facial recognition.

The report will be completed in early spring. In the next issue of the *MDA Update* (Summer 2002), look for information on how to get your free copy.

## TELECOM, AUTOMOTIVE MARKETS FUEL GaAs DEMAND

With the trend toward high-bandwidth communications in more compact, portable electronics, compound semiconductors like gallium arsenide (GaAs) have steadily been gaining ground on traditional silicon components. In contrast to silicon, GaAs offers faster operating speeds, consumes less power, and has light-emitting and detecting properties needed for optoelectronic devices. According to *Compound Semiconductor* magazine, the market for GaAs devices was over $2 billion in 1999, and some estimates show that figure growing to the tens of billions by 2003, even with the current economic downturn. To realize this level of growth, however, GaAs houses will need to better compete with the high level of device integration on a chip provided by silicon.

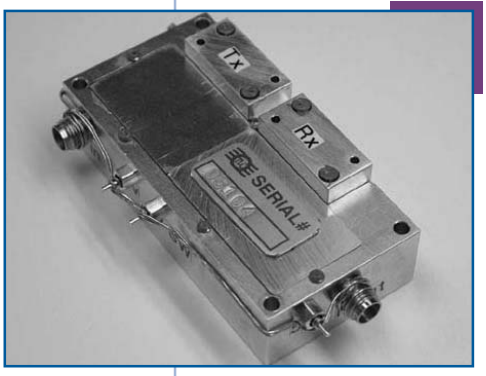
With advanced molecular beam epitaxy (MBE) growth processes and the use of 6-inch GaAs wafers, TLC Precision Wafers, Inc. (Minneapolis, MN), is a small company ready to meet these demands. In BMDO-funded research, the company is developing a GaAs-based integrated transmit/receive (T/R) module that will reduce the size and lower the cost of the ground-based, phased-array radar imaging systems used to detect and track missile attacks. This T/R module technology could also help reduce the size and lower the power consumed by cell phones, collision avoidance radar in cars, and microwave radio links.

In another BMDO-funded project, TLC developed technology to protect satellite communications electronics from radiation-induced, single-event upsets (SEUs). (GaAs, although more radiation-hard than silicon, is still susceptible to SEU spikes in radiation exposure.) The simplifications in circuit design resulting from this technology should reduce the cost of satellite telecommunications systems.

This research will complement an extensive array of products that TLC has developed with the help of other government and commercially funded R&D contracts. For instance, the company's "O" chip combines an oscillator (the circuit that transmits electromagnetic signals) that operates from 2 to 80 GHz with an output buffer amplifier. This chip replaces circuits in radar or communications systems that cost 4-times more and are 1,000-times bigger. In addition, TLC offers ultra-high-power amplifiers, phase modulators, millimeter wave switches, and other devices for the telecommunications and automotive markets. "Right now," says TLC president Tim Childs, "we've got a backlog of orders that will keep us busy for the next two years at our current production levels."

To help meet this backlog, along with the anticipated growth in market demand, TLC is now scaling up its production equipment to make the transition from an R&D house to a manufacturing firm. In the capital-intensive microelectronics industry, this will take a lot of money—probably in the seven figures. But, with realistic sales projections in the eight figures by 2007, this money shouldn't be hard to come by, even with today's investment climate.

*—T. Lynch*




***Ready to go.*** *TLC's transmit/receive module could help reduce the size and lower the power consumed by cell phones, collision avoidance radar in cars, and microwave radio links.*

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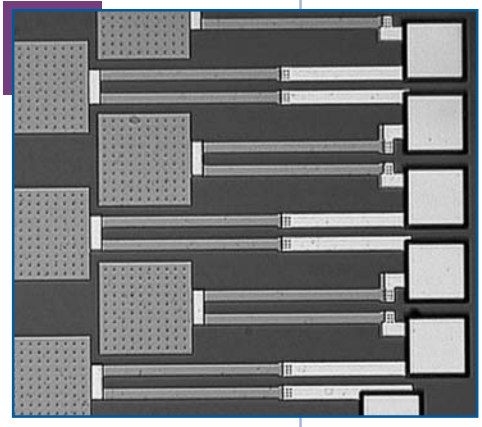
### Attention Researchers

*Want to be featured in the* MDA Update*? If your company is developing a BMDO-funded technology, and it has strong commercial potential, then call editor Patrick Hartary at (703) 518-8800, ext. 222. We can help spread the word about your innovation to the media, large commercial businesses, venture capitalists, associations, and other government agencies.*

MEMS

## THIN-FILM SHAPE MEMORY ALLOY: MEMS THE WORD



***Mirror magic.*** *TiNi Alloy makes thin-film SMA levers that can push micromirrors up or down, redirecting light beams for optical switching.*

If human muscle were made out of the shape memory alloy (SMA) Nitinol, a boxer would pack a punch with 300-times more force than usual and be able to jab up to 1,000 times a second. That kind of force and speed would be useful in the ring, but it is even more useful in the realm of micro-electro-mechanical systems (MEMS) where lengths are measured in microns and mechanisms operate at kilohertz frequencies.

The unusual properties of Nitinol, an alloy of 55-percent nickel and 45-percent titanium, have been known since its 1962 invention at the U.S. Naval Ordnance Laboratory. An original shape is imparted to the material at temperatures above 500ºC. When cooled, Nitinol can be formed into a new shape. Then, when heated above its transformation temperature of 90ºC, it will revert back to its original shape. If it meets resistance along the way, it generates force. Normally a one-time-only event, this process can be made reversible. Heated to near its transformation temperature (in a range of 70 to 90ºC), it will start to revert back towards its original shape, but retain its new one.

TiNi Alloy Company (San Leandro, CA), aided by funding from BMDO and several U.S. government agencies, has researched and developed a whole new class of thin-film SMAs used in MEMS devices. TiNi's SMAs are made using sputtering techniques to deposit a layer of nickel-titanium alloy onto a polished silicon substrate. This thin film can then be micromachined using MEMS photolithography and selective etching techniques.

Large mechanisms can use electromagnets, motors, or solenoids to do work, but at the MEMS level there are no equivalents. When an electric current of 50 to 150 milliamperes is passed through a thin-film SMA actuator, it can produce a force of 10 joules per cubic centimeter per cycle. That is about 10 times more work output per volume than an electrostatic or thermopneumatic actuator. Lightweight, capable of working at high pressures, and remotely resettable, thin-film SMA has a variety of potential applications as components in miniature valves, pumps, relays, switches, and stents.

Out-of-plane actuation—the use of thin-film SMA levers to push other components in three dimensions rather than only two—is a largely unexplored field. When BMDO funded the company for out-of-plane actuation in the MEMS arena, it originally hoped to improve field-emission display technology. However, the real payoff might come in supporting a burgeoning optical switching industry where multi-use mechanisms that can move a mirror or redirect a light beam a few hundred microns at kilohertz speeds would have potential for regulating transmission wavelength and frequency.

One problem limiting Nitinol use has been its low transition temperature. In another project, TiNi Alloy Company, with support from the National Science Foundation and Defense Advanced Research Projects Agency, has recently tested a trinary titanium-nickel-hafnium (TiNiHf) alloy that seems to have essentially the same properties as Nitinol, but a higher transformation temperature in the 150ºC range. That would make TiNiHf SMA possibly attractive to the automotive industry for under-the-hood applications where higher operating temperatures are encountered. The company wants to retain its focus on research and development and seeks to license its existing patents.

*—A. Gruen*

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**"The desire to know is natural to good men."**

***—Leonard de Vinci***

## FOR A HEALTHY NETWORK, CONSUME LESS FIBER

When the World Trade Center towers were destroyed on September 11, 2001, many firms that had occupied the towers moved elsewhere and struggled to regain telecommunications service. Delays of weeks or months seemed probable. However, by deploying free-space optical (FSO) equipment provided by LightPointe Communications, Inc. (San Diego, CA), a local exchange carrier restored high-speed (OC-3) service to one of its clients in just one weekend.

The major problem with fiber-optic cable is that it takes a significant amount of time, money, and effort to lay, to repair, or to remove. In an ideal telecommunications world, lasers could just transmit through air instead.

In fact, lasers have been used for secure line-of-sight communications since the 1960s, but until recently no one had developed FSO technology that could match the quality and capacity of fiber optics. That changed starting in 1998, when BMDO funded Dr. Heinz Willebrand at Eagle Optoelectronics (Broomfield, CO) for SBIR research into designing multiwavelength, high-performance, eye-safe laser communications network equipment. Later that year, Willebrand founded LightPointe.

Historically, FSO transmission quality has been limited by dense fog that absorbs, reflects, or scatters beams. The simplest way for FSO transmitters to overcome dense fog is to boost signal power, but therein lies a safety problem: at a wavelength of 850 nanometers (nm), near-infrared light is absorbed by the human retina, and regulations require laser use at low power (below 100 mW). BMDO supported research into the design of a 1550-nm wavelength transmitter/receiver (called a transceiver) that could operate at approximately 2 watts. All other conditions being equal, a higher-powered laser can transmit about five times as much data as a lower powered one.

Pockets of hot or turbulent air that act as lenses—a problem called scintillation—has been another obstacle to reliable high-speed FSO communications. In 1999 and 2000, LightPointe received BMDO SBIR funding for continued development of not only a higher-powered FSO laser transceiver but also an integrated microwave radio frequency (RF) backup to make FSO communications more reliable. Eventually, LightPointe solved the scintillation problem by using three beams separated by 200 millimeters to send the same signal, with excellent odds that at least one of the beams would get through (a technique the company calls spatial diversity). With the combination of higher power and spatial diversity, LightPointe chose to use the RF equipment as an out-of-band management tool to interface with standard industry management systems.

The latest version of LightPointe's FlightSpectrum™ product, to be generally released in the first quarter of 2002, will provide a 2.5 Gb/s capacity (OC-48) over a distance of up to 1,000 meters. The company plans to release later versions that will use an auto-tracking system to boost that range to 2,000 meters, and a multi-wavelength transceiver that will increase capacity to 10 Gb/s (OC-192).

The lesson of September 11 is not likely to be ignored by either commercial or military telecom service providers. FSO equipment is relatively mobile and can be deployed or redeployed quickly. In theory, FSO could be supplied in lieu of cable to commercial and residential customers desiring high-speed access and bandwidth-intensive services. Looking ahead to the future, LightPointe intends to become part of the emerging trend towards bypassing existing phone or cable lines in last-mile connectivity to the home.

*—A. Gruen*

***Getting to the point.*** *LightPointe's FlightPath™ transceiver sits on a Dallas rooftop and points towards a paired cousin below. Free-space optics provide the quality of fiber-optic communications without laying cable and tearing up streets.*

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POWER GENERATION

## FLYWHEEL RESEARCH ADVANCES "POCKET ROCKET" ENGINE SYSTEM

***Guiding force.*** *Quoin's 10-horsepower turbine is a key component of a flywheel-based attitude control device for BMDO missile interceptors.*

A new attitude-control and maneuvering device for BMDO missiles has given a boost to a tiny free-piston engine system that could generate up to 80 horsepower (hp). The system—which will initially be designed in 1- to 10-hp packages small enough to fit in your pocket—may one day replace batteries found in consumer products ranging from motorized bikes to industrial power drills.

Quoin International, Inc.'s (Ridgecrest, CA) attitude-control device will rely on a super-small turbine to spin an array of small flywheels at over 100,000 revolutions per minute (RPM)—up to 500,000 RPM during stress testing. The flywheels produce a gyroscopic motion that improves the accuracy of missile interceptors. BMDO's SBIR program funded the development of both the turbine and the flywheels, which are key components of Quoin's PowerQuick™ micro-engine system.

Compact and powerful, PowerQuick's engine will use propane, butane, or diesel fuel to produce a continuous stream of highly pressurized air that spins a turbine. Flywheels and actuators can be connected to the engine's drive train to generate electrical power and mechanical energy, respectively. Energy conversion efficiencies are in the range of 60 to 70 percent, which is very high for an internal combustion engine.

Quoin is now looking into engineering issues, such as transmitting the power from the ultra-high-speed turbine to low-speed rotary applications. Ten horsepower is far too much power for today's battery-operated industrial drills and other power tools, for example, which typically run on 1 hp. The company is also investigating how to design power conditioners to manage electrical power and how to control the heat produced by the fuel combustion process, which can lead to turbine inlet temperatures up to 1,000° F.

Moving toward commercialization, Quoin is working with a large power tool manufacturer to develop consumer products based on its PowerQuick technology. The company has also entered into joint agreements with a high-pressure water pump manufacturer. Currently, the wildfire industry uses a bulky two-stroke internal combustion engine to pump water at high velocities. Due to new environmental regulations, this engine can no longer be sold in new equipment and will be replaced with cleaner burning ones. While meeting these regulations, Quoin's technology will also significantly reduce the weight and extend the operating life of a new engine.

Quoin is looking for other industry partners to further develop and commercialize its attitude-control and PowerQuick technologies.

*—P. Hartary*

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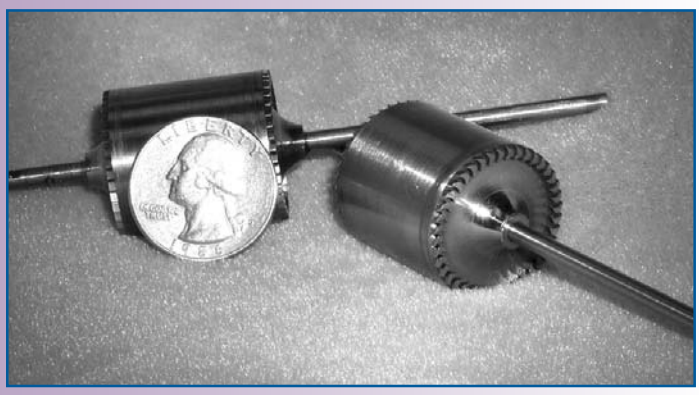


***Speed demon.*** *With BMDO funding, Quoin developed an 80-horsepower turbine that was used to spin a small flywheel up to 500,000 revolutions per minute for stress testing. Commercially, this turbine is ideal for power tool applications.*

POWER GENERATION

## WHEN THE GOING GETS HOT, ADD TPVs

Solar power advocates have already seen the light; now they are feeling the heat. A new class of photovoltaic cells called thermophotovoltaics (TPVs) that convert heat into electricity may soon find their way into both solar power systems and home heating furnaces.

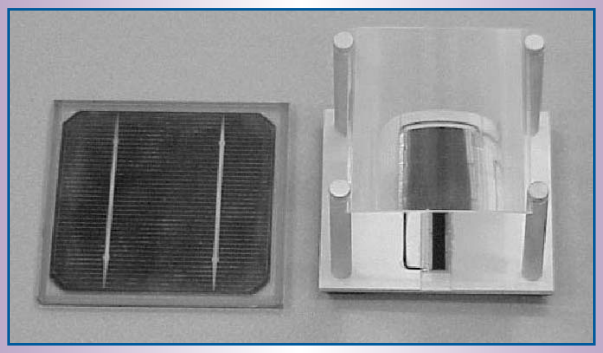
JX Crystals, Inc. (Issaquah, WA), with funding from BMDO, DOE, and NASA, manufactures gallium antimonide (GaSb) solar cells that can be stacked underneath indium gallium phosphide/gallium arsenide (InGaP/GaAs) dual junction solar cells. Since GaSb cells absorb infrared radiation to produce current, they can provide an extra boost to cells that are transparent to the longer wavelengths. The more sunlight that is focused on a stacked array, the greater the efficiency boost. Tests confirm a gain of at least 6-percent efficiency under concentrator lenses, increasing the triple-junction cell's solar conversion efficiency to over 30 percent, and company researchers have identified a clear path to 40-percent conversion efficiencies for the future.

For the BMDO SBIR contract, JX Crystals manufactured approximately 30 InGaP/GaAs/GaSb circuits each producing between 3.1 to 3.3 watts. Larger production runs are possible. Mechanically stacking GaSb TPV cells underneath solar cells is relatively inexpensive compared to other methods such as metal organic chemical vapor deposition, because JX Crystals manufactures TPV cells using diffusion without toxic gases. The cost of TPV cell manufacture is almost certain to come down even further for all applications once JX Crystals begins mass production for a major market. It may have found one in combined heat and power (CHP) systems. The company demonstrated a fuel-fired stove, lined with GaSb-only cells, that produced 25,000 Btu/hr of heat and 100 watts of electricity, and is working with U.S. and foreign national partners to produce bigger CHP systems generating one to two kilowatts of power.

With size and weight always at a premium in spacecraft design for missile defense, military communications, and commercial applications, the benefit of using the more efficient PV/TPV (or "tandem") combination in next-generation space-based power systems is apparent. The same also holds true for solar-powered aircraft design. In either case, TPV booster cells could provide more power with very little additional cost in weight.

The use of tandem arrays could finally push solar power into being an affordable, competitive alternative to fossil fuels. JX Crystals supplied one energy company with information on what it would cost to supply 50 megawatts of 30-percent-efficient tandem cells under concentrating lenses to be operated in the deserts of southwest United States and Mexico. JX Crystals welcomes inquiries on TPV costs and capabilities, and currently seeks investment to build a facility that can annually manufacture circuits generating a total of 100 megawatts of electricity.

—*A. Gruen*



***Low versus high.*** *On the left, a conventional solar cell at 10-percent efficiency with an area of 100 cm²; on the right, a JX Crystals 3-watt solar cell under a concentrator lens at over 30-percent efficiency with an area of 7 cm².*

*"[In the BMDO SBIR project]…we showed that mechanically stacked circuits using light-sensitive top cells and IR sensitive bottom cells can be easily manufactured with an innovative top-side ribbon bonding method… By using mechanical stacked cells in concentrator arrays, we can identify straightforward paths to 40-percent efficient circuits."*

*Dr. Lewis Fraas*
*President, JX Crystals*

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FEATURE

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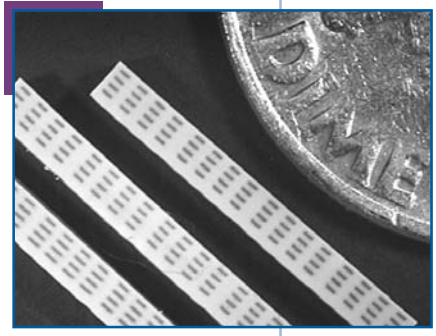

***Power points.*** *Tapping its nanoexpertise, Nanomaterials Research is developing multilayer capacitor array components for aerospace applications.*

the visible and near-infrared regions (0.3 to 5.0 µm). However, many inherent difficulties and limitations exist in processing AlON powders. In addition, the high cost of AlON powders and components also prohibit widespread application.

A proprietary and scalable mechanochemical process is the focus of the investigation, which is still in its scale-up phase. The goal of the research is to optimize and characterize the synthesis, structure, chemistry, particle size, and particle size distribution of AlON. Nanomat believes its process will be cost-effective and less prone to contamination than today's carbothermal and solid-state reaction processes.

Nanomat has crafted a profitable business supplying sample quantities of nanomaterials to manufacturers. The company is now looking for additional capital to fund new employees, equipment, and facilities.

## NanoPowder Enterprises

NanoPowder Enterprises, Inc. (NEI; Piscataway, NJ), is a specialty nanomaterials company. It uses proprietary vapor-phase and chemical synthesis techniques to produce nanoscale electrode materials for lithium-ion and hybrid energy storage devices, hard carbide coatings, hard and transparent coatings on polycarbonate substrates, specialty oxide powders, and inorganic/organic hybrid nanoparticles.

For example, NEI has developed a low-pressure, high-rate combustion flame process to synthesize oxide nanoparticles with minimal aggregation. The process, called combustion flame-chemical vapor condensation (CF-CVC), combines a vaporized metal-organic precursor compound with an oxygen-containing combustion gas to form a precursor/combustion gas stream. This gas stream is then delivered to a flat-flame combustor in a low-pressure reaction chamber where it is heated for only a fraction of a second. A continuous stream of nanoparticle clusters exits from the combustion zone and the powder is collected.

CF-CVC oxide nanoparticles offer a narrow particle size distribution because the temperature distribution and gas phase residence time of the precursor/combustion gas stream are uniform over the entire surface of the burner. The particles are also 50-percent smaller in size than those produced by competing methods; primary and secondary particle sizes range from 15 to 25 nanometers and 100 to 150 nanometers, respectively. In addition, the reduced pressure environment inside the reaction chamber enables the production of oxide nanoparticles with minimal aggregation.

A significant portion of NEI's CF-CVC research and development was funded by U.S. Navy SBIR contracts. However, BMDO has funded the technology's scale-up, which could enable larger scale production of higher performance, nanopowder-based batteries, photovoltaics, sensors, and electromagnetic shields. To produce commercial quantities, NEI is developing a flash evaporation system to deliver the precursor/combustion gas stream to the burner at higher rates. In addition, NEI's partner, the Center for Nanomaterials Research at Rutgers University, is providing scientific insights into critical processing parameters using *in situ* laser diagnostics and computer modeling.

NEI will sell or license its materials technologies to larger manufacturing houses. For example, one of the company's oxide nanopowders can be used to make anode materials for uninterruptible power supplies and automotive batteries. Small particles increase the rate capability of the anode, resulting in faster energy charge and discharge. NEI is working with Telecordia Technologies, formerly Bellcore, to implement this material for commercial power applications.

## Nanomaterials Research

As an early start-up company, Nanomaterials Research Corporation (NRC; Longmont, CO) first developed novel processes for manufacturing nanopowders. Fabrication technologies were then developed to exploit the unique properties of these nanopowders. These nanopowders have been processed into many different electrical devices, ranging from capacitors to gas sensors.

For example, NRC has developed a suite of gas sensors that are based on semiconducting metal oxides. These materials readily adsorb certain gases and generate an electrical response proportional to the concentration of the gas present. Because these reactions are surface-dominated, the high surface area of nanomaterials plays a key

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role in the magnitude of the response.

Sensors for hydrogen (at two concentration levels) and methane are already available for sale in prototype quantities. Sensors for ammonia, nitrogen oxides, and volatile organic compounds will be available in mid-2002. Other products being developed include sensors to detect alcohol in breath, determine air-to-fuel ratios, and measure concentrations of fluorine, carbon dioxide, and hydrogen sulfide gases. The research to develop these sensors was primarily supported by SBIR programs from agencies such as DOD, DOE, EPA, and NIH. Sensor customers and partners include 3M, Dow, Chevron, and Eaton Corporation.

Another area where nanomaterials play an even greater role is passive electronic components. These devices are primarily surface-mount style and the prevailing trends are toward lower raw materials and manufacturing costs, smaller part sizes, higher performance, and increased reliability—all of which are influenced by the use of finer ceramic powders.

In one project, NRC is developing high-performance ceramic overcurrent protection devices with BMDO SBIR funding. These devices will exhibit very long lifetimes even with frequent exposure to high currents. Today's polymer-based overcurrent devices, which are typically found in many power distribution systems, often fail upon repeated high current episodes. NRC has already established a strategic relationship with a Fortune 500 company for applications in the automotive and telecommunications fields.

The BMDO SBIR program is also funding NRC's development of multilayer inrush current limiters, which can help protect sensitive microprocessors from damage due to overcurrent conditions. These circuit protection devices use negative temperature coefficient ceramics that have been processed in a multilayer configuration with low-cost internal electrodes. NRC has already provided demonstration devices to a leading manufacturer of such products, with the intent of developing strategic relationships for technology transfer and commercialization.

To expedite the commercialization of its technologies, NRC divided in March 2001 into two distinct companies: Nanomaterials Research, LLC (NRLLC), and NanoEnergy Corporation. NRLLC focuses on nano-engineered device development and manufacturing and derives most of its revenue from a combination of government- and commercially sponsored research and development contracts and prototype device sales. NanoEnergy concentrates on developing and manufacturing nano-scale powders and emerging powder-based energy technology. Its revenues have come primarily from private investments. Both companies seek additional partnerships to explore new applications within their respective technology areas.

## Nanocrystals Technology

Nanocrystals Technology, LP (NCT; Briarcliff Manor, NY), makes nanocrystalline phosphors. These nanocrystals offer very small particle sizes, yet are able to maintain their luminescence efficiency. But the company isn't interested in selling these materials outright. In fact, it is using them to create new digital x-ray imaging products for dentists and doctors.

With funding from BMDO's SBIR program, NCT has incorporated its nanocrystalline phosphors in a microchannel plate to create a device it calls a "composite phosphor screen." The screen, which converts invisible radiation (e.g., x-rays) into visible light, minimizes light reflectance. As a result, contrast and resolution are dramatically improved when the screen is combined with a light-collecting device, such as a CCD/CMOS detector. With x-ray, ultraviolet, or visible radiation detectors, the device could be used in missile detection and tracking.

X-ray systems using NCT's composite phosphor screen technology would also be ideal for use in dentistry. Dentists have switched to digital imaging systems because they transmit less radiation to their patients. But these systems do not offer the same resolution as film-based devices. When problems are suspected, dentists usually revert back to film for more accurate diagnoses, thus two systems can be found in most offices. More portable and affordable, NCT's technology could replace these two systems with one unit, while requiring far lower radiation exposure than previous digital imaging systems.

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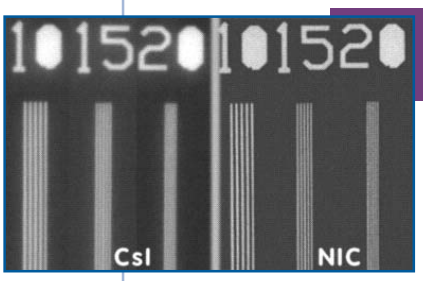


***Seeing the light.*** *Using Nanocrystals Technology's digital x-ray system, doctors will achieve 2- to 3-times the resolution of commercially available cesium iodide-based systems at similar dose rates and a lower price.*

MDA Update
SPRING 2002



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Address Correction Requested

*NCT's subsidiary, Nanocrystal Imaging, has raised over $5 million to commercialize x-ray digital imaging systems.*

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Several dental prototypes were developed and are currently being tested by dentists across the country. Later this year, one of these devices will be submitted to the Food and Drug Administration for regulatory approval.

NCT's technology will interest doctors, too. High-resolution, high-contrast images are required for many x-ray medical imaging systems, particularly those used for mammography. The resolution of x-ray film and digital mammography systems is currently limited to 20 line pairs/mm and 10 line pairs/mm, respectively. Compared to existing systems, NCT's technology could deliver 2- to 3-times higher resolution while maintaining high contrast. A portable x-ray imaging system capable of digital, large area imaging for teleradiology could be built. This system may allow doctors to remotely diagnose and treat wounded soldiers in the field or people living in distant areas. NCT is currently testing a prototype with various CCD cameras to optimize its performance.

With the goal of developing superior x-ray digital imaging systems, NCT has formed a subsidiary called Nanocrystal Imaging Corporation (NIC). NIC has raised over $5 million in funding from private investors, mostly doctors. The company is currently seeking industry partners and additional funding sources (e.g., venture capitalists and angel investors) as it completes the product development stage and begins production.

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